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ABSTRACT:

The rate of corrosion of reinforcement material 1 in concrete or like material structures 2 is monitored. The reinforcement material forms, with the concrete a corrosion half cell, and is connected via a current measuring device such as a zero resistance ammeter ZRA to a probe 50 having an annular surface portion mounted for rotation and covered with a water absorbing portion such as a sponge. The sponge is made damp and the probe is moved over the surface of the concrete. Readings of current may be taken continuously or at discrete intervals. A second annular surface with absorbent covering may be provided adjacent the first and the potential between the second surface and the reinforcement may be monitored. <IMAGE>

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(54) Monitoring corrosion of elements embedded in concrete

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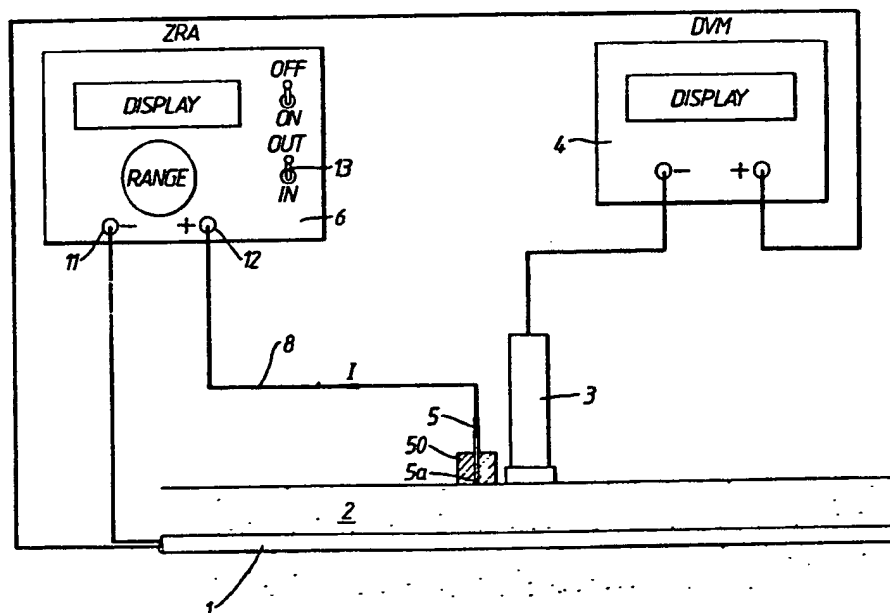


Fig.1.

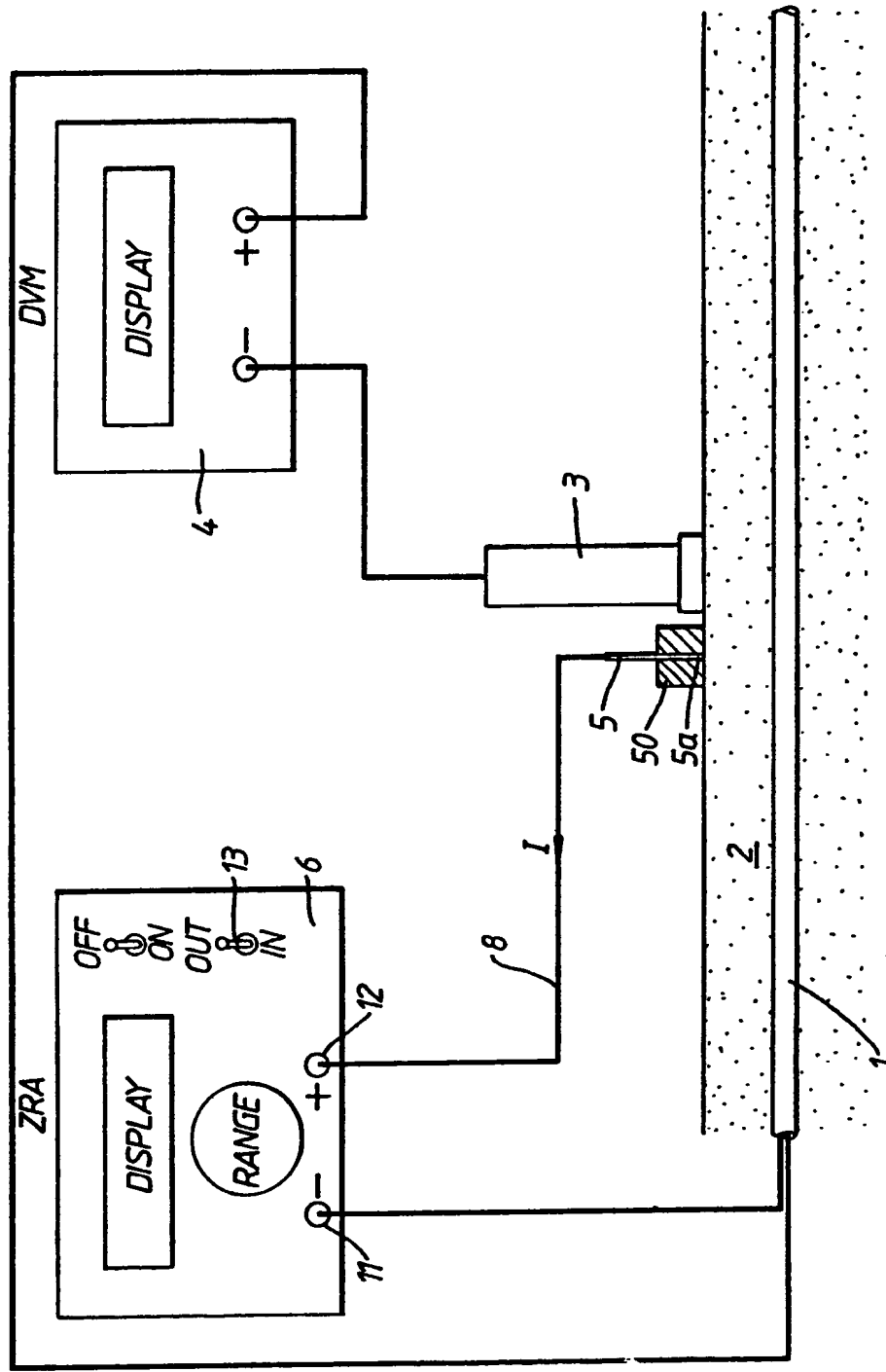


Fig.1.

2/7

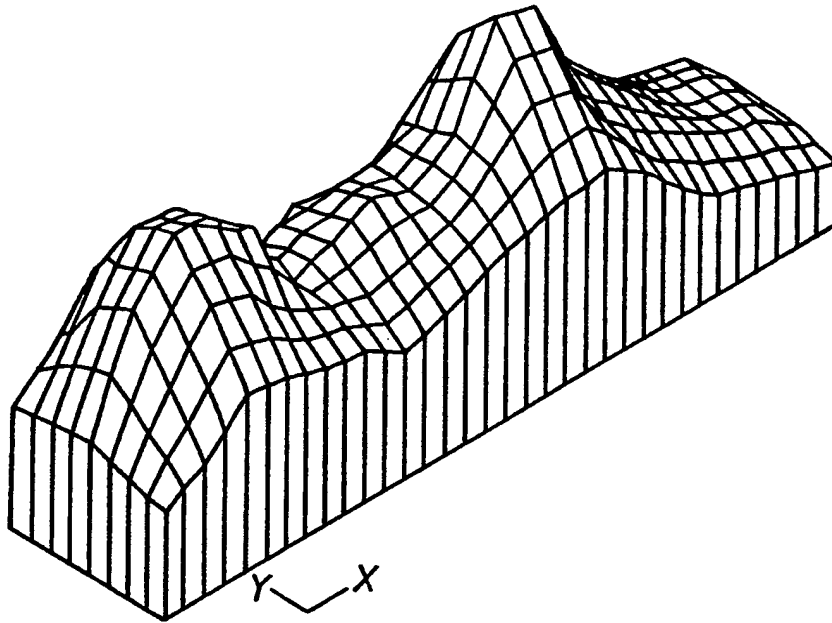


Fig.2A.

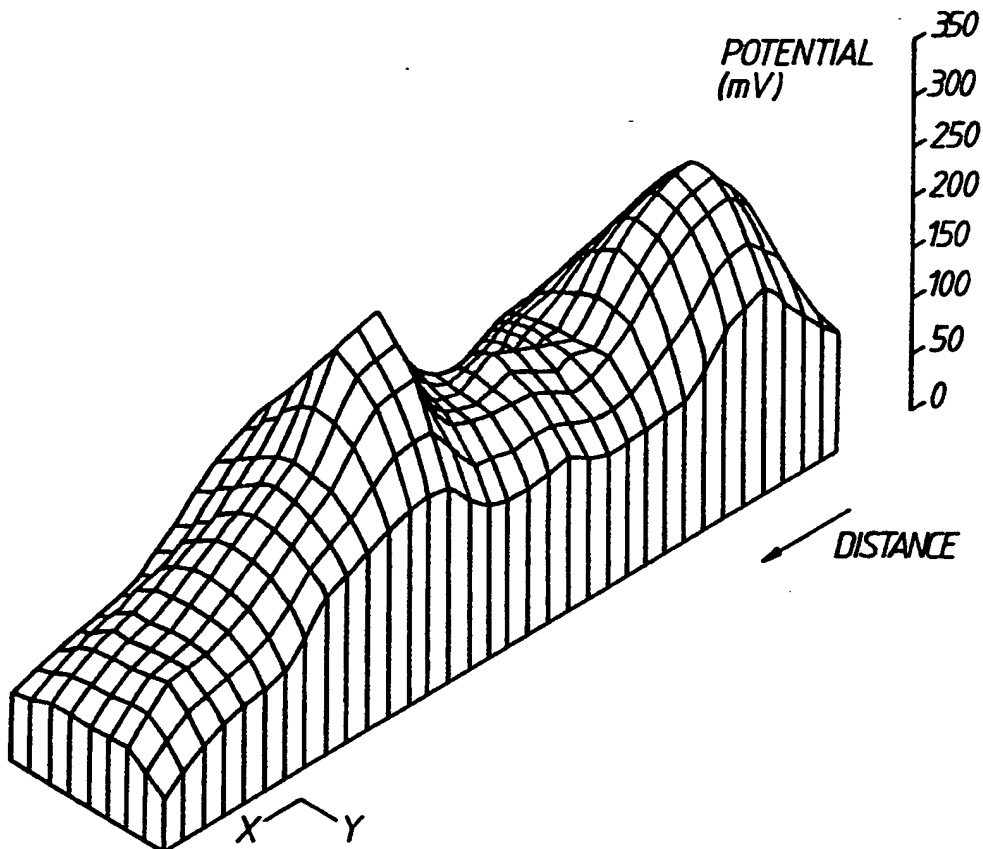


Fig.2B.

3/7

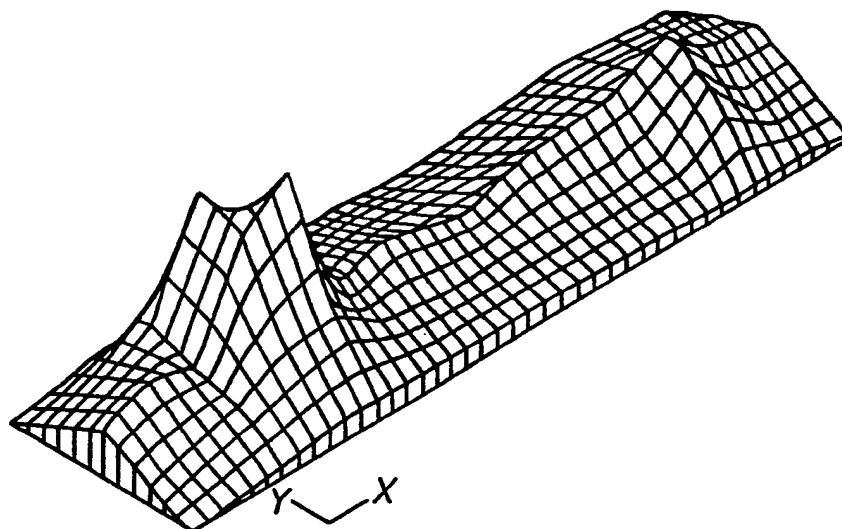


Fig. 3A.

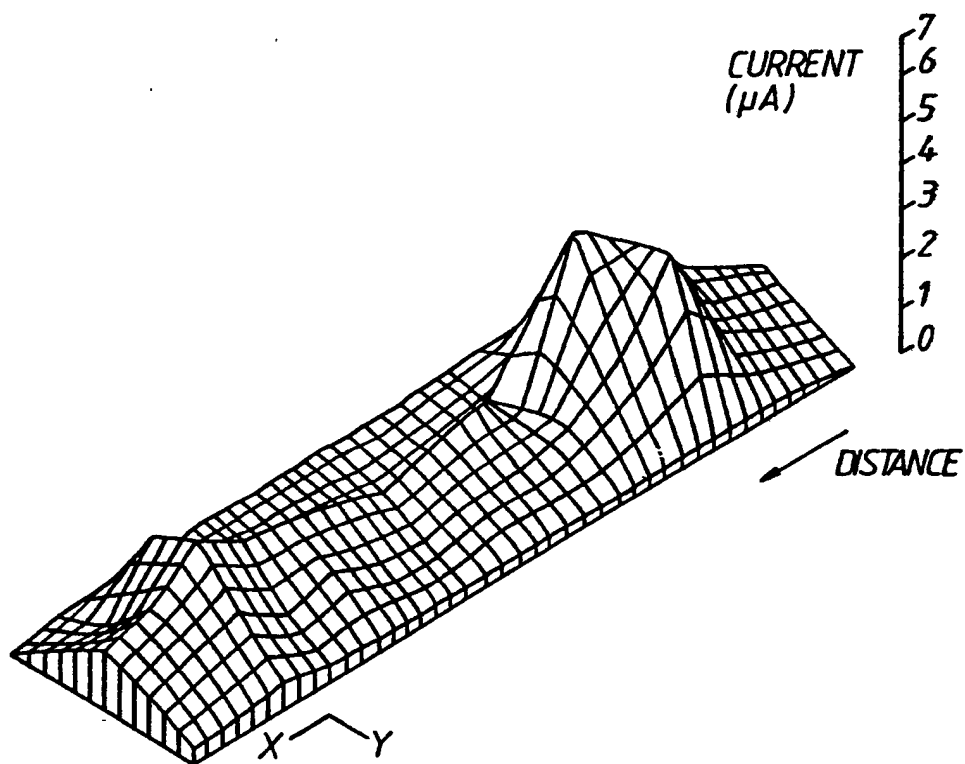


Fig. 3B.

4/7

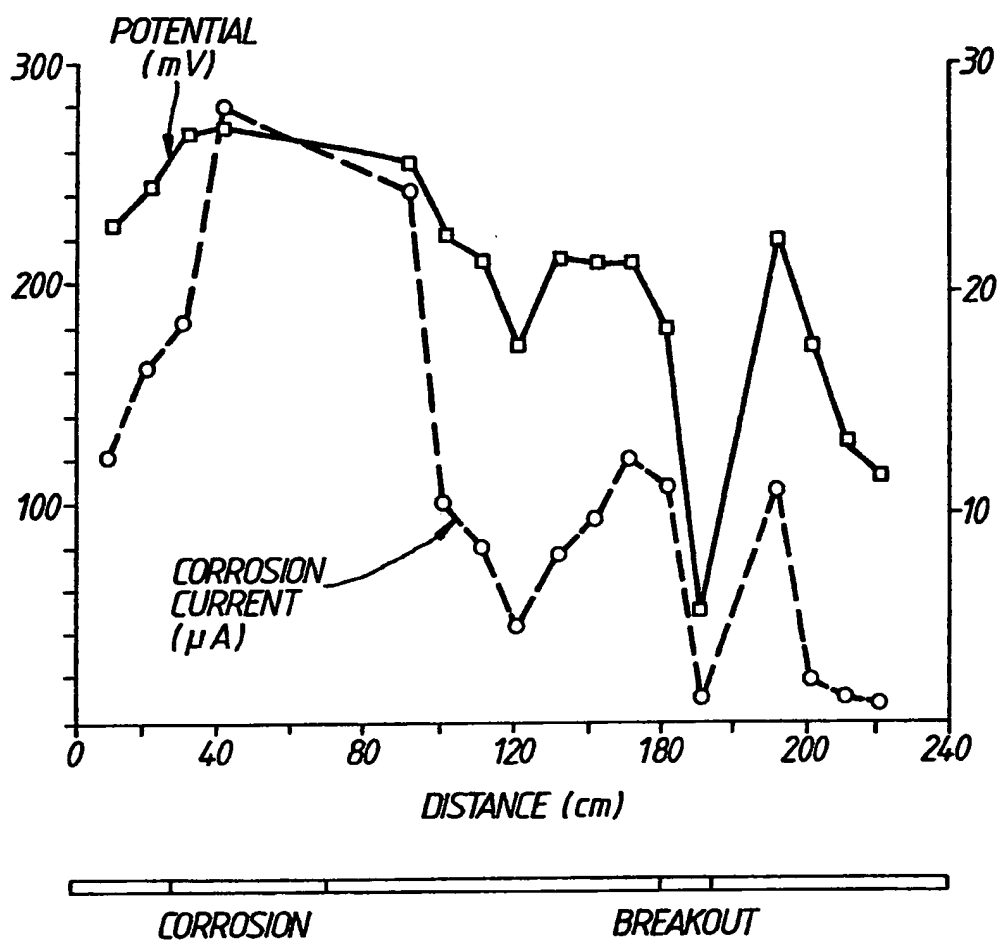


Fig. 4.

5/7

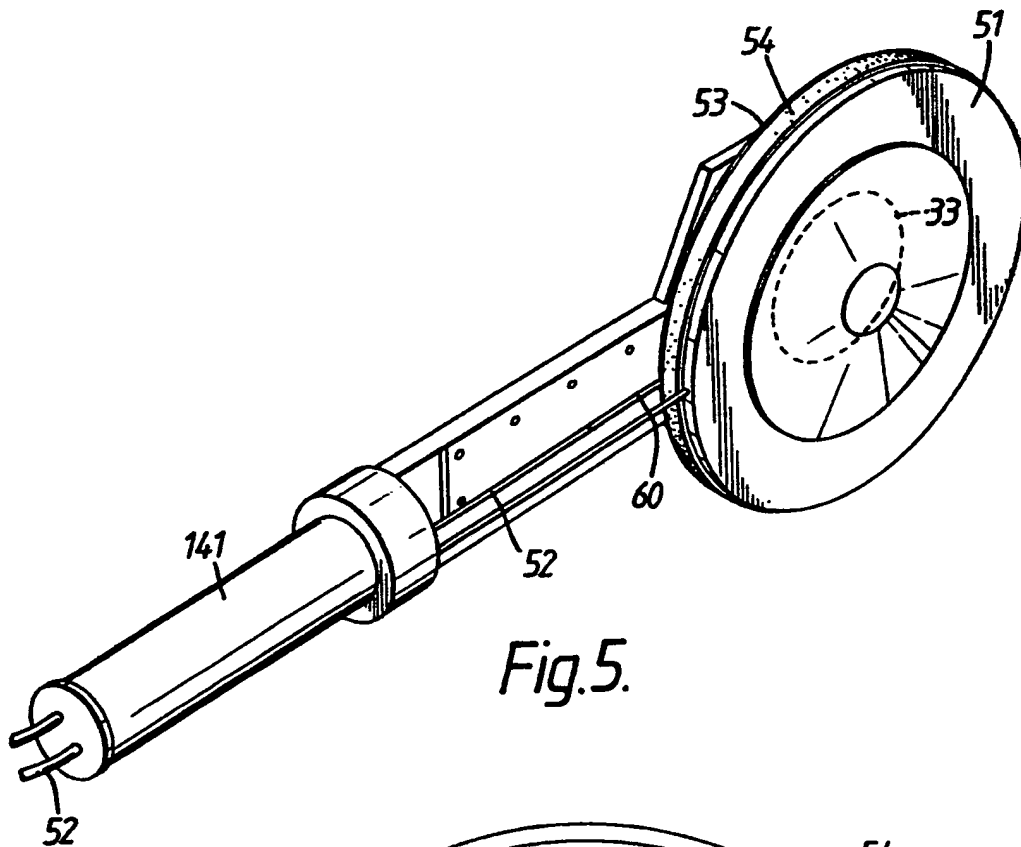


Fig. 5.

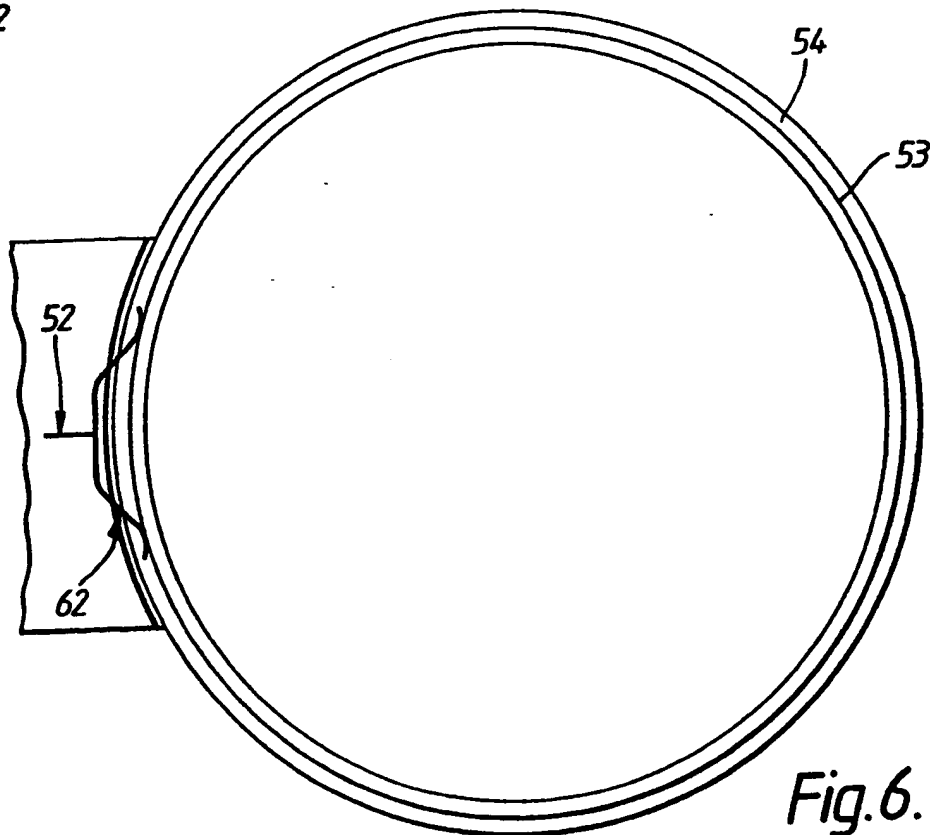
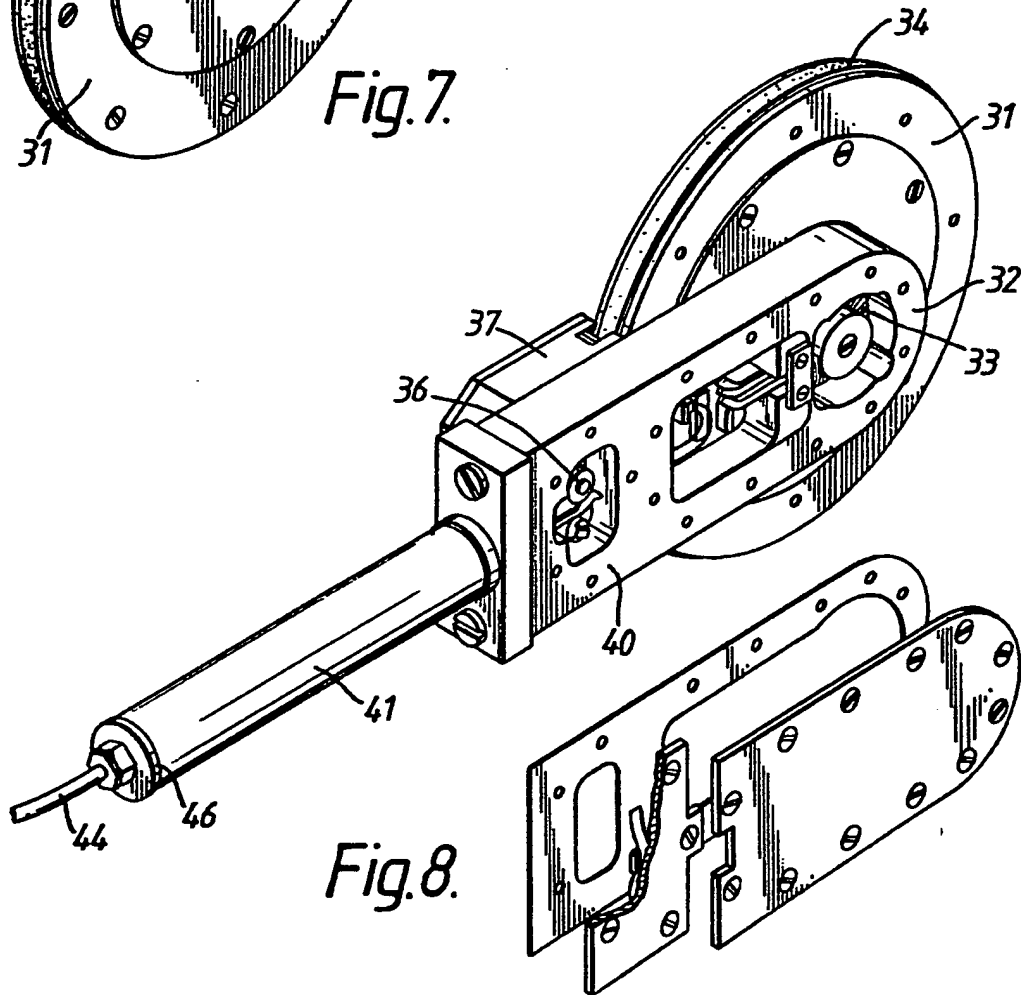
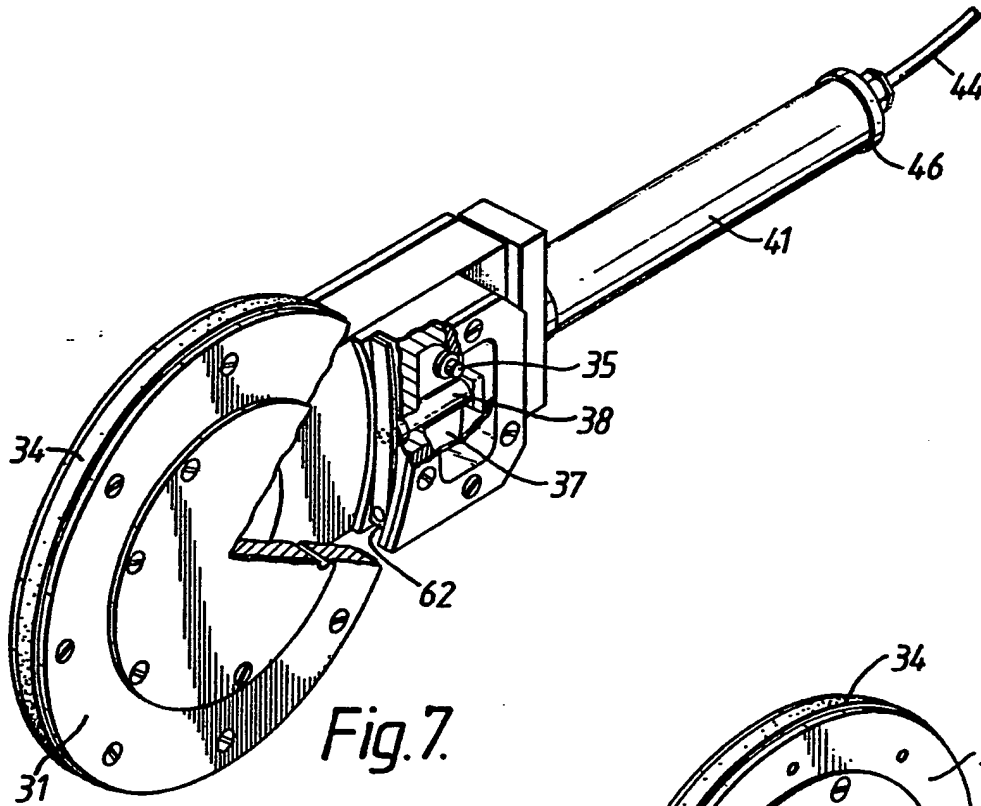
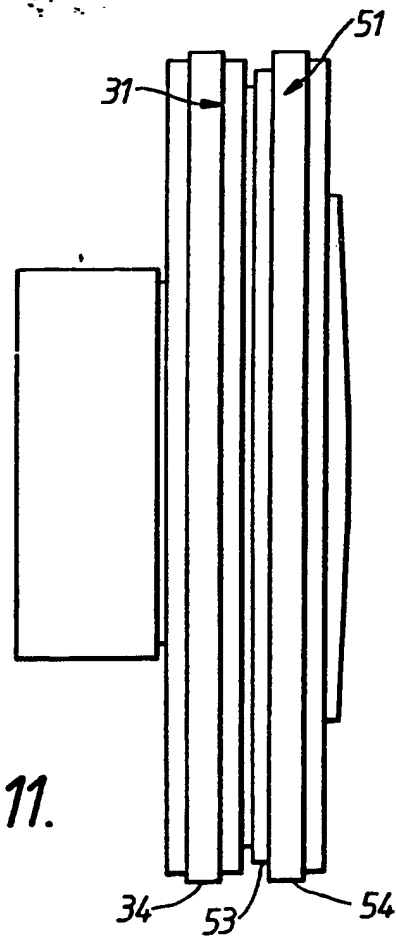
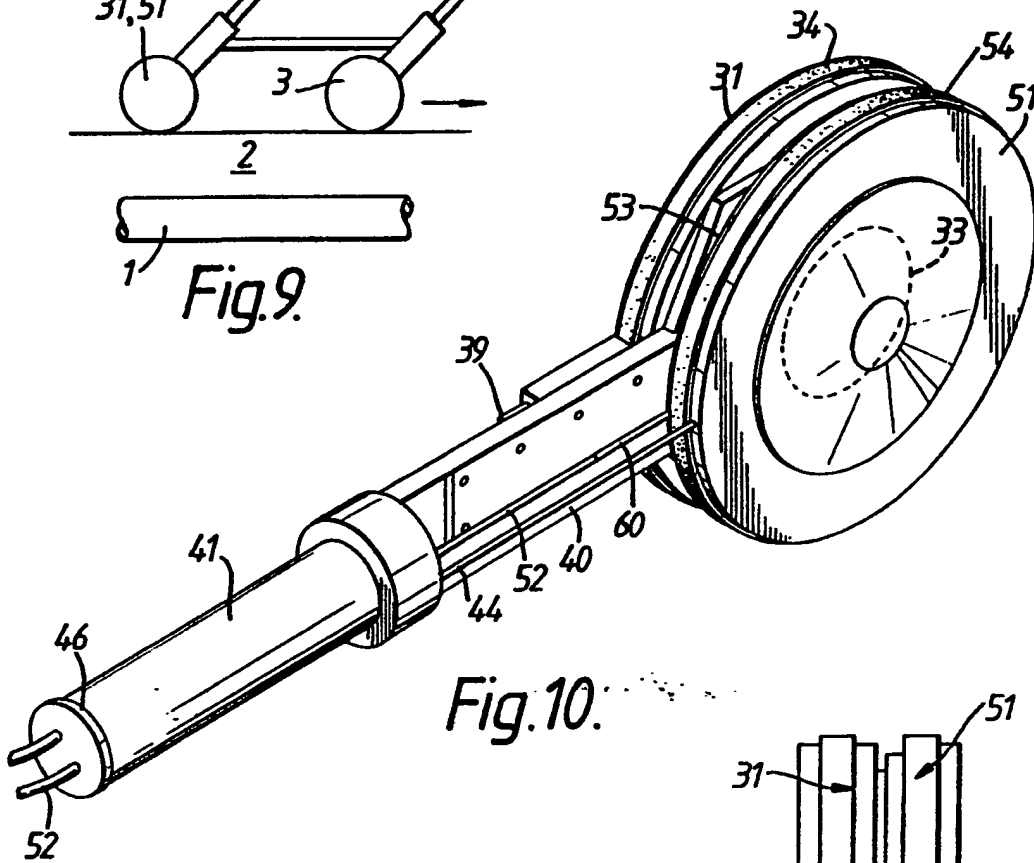
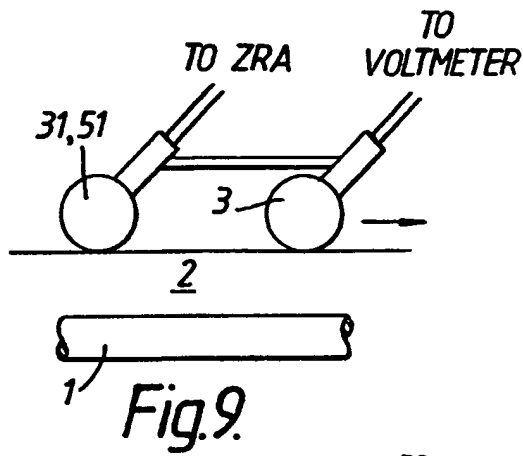


Fig. 6.

6/7





CORROSION MONITORING

This invention relates to corrosion monitoring and particularly, but not exclusively, to an apparatus and method for enabling the rate of corrosion in a structure to be monitored.

There are several techniques available for monitoring corrosion in structures such as steel reinforced concrete. It is known that corrosion of steel in concrete, due to salt penetration or carbonation for example, gives rise to localised areas of electrochemical action, referred to herein as "corrosion half cells", which give rise to a potential which can be detected. Detection techniques include measuring the potential at regions of the structure using an electrolytic reference half-cell, as described for example in GB 2157441. The electrochemical potential of steel in concrete when measured at the surface gives an indication of the likelihood for the bar to corrode. This merely indicates a thermodynamic equilibrium and provides no quantitative information regarding the corrosion rate. For instance where conditions of oxygen or moisture starvation occur, the steel shows high negative potentials, but the corrosion rate is negligible and does not pose a durability problem. Thus a method capable of quantitatively estimating corrosion rates of embedded steel is required.

Further, the reference half cell, positioned on the outer concrete surface, does not measure the exact corrosion potential at the steel. Ohmic effects exist which are dependent on depth of cover, concrete resistivity and the type of corrosion. This ohmic effect may change both across the structure and with time as the local moisture and salt content vary. This creates an error of between 10-50mV in the measured potential which can be of considerable importance since

it is recommended that the absolute potential be used in assessing the corrosion hazard.

Other techniques are manual inspection and chemical analysis. Use of one or more of these techniques enables a relatively accurate picture to be obtained concerning the position of corrosive sites and the severity of corrosion or risk of future corrosion at those sites. However, no information can be derived concerning the rate at which corrosion is occurring.

Such information is extremely desirable since it enables more accurate and reliable forecasts to be given concerning the safety of a structure in the future, and also concerning the effects of different environmental conditions on corrosion rate.

A current technique for monitoring corrosion rate is known as "linear polarisation". In this technique, the steady state potential of a corrosion half cell of the structure is perturbed by causing a small current to flow from an external source to the corrosion half-cell and measuring the resulting change in potential. This can be used to give an estimate of the current (the so-called corrosion current) which would be present in the absence of the small perturbing current. An estimate of the corrosion rate can then be derived by considering the corrosion current per unit area. This technique is presently carried out using a potentiostat to apply a fixed perturbing current or voltage to the structure. Such a potentiostat is the WENKING POTENTIOSTAT LT 78, and its method of use is described in operating instructions issued therewith. The use of such a potentiostat has several disadvantages. It is bulky to use, so has only limited field application. It is generally driven from the mains, which introduces undesirable noise into the measurements. It is complex to use since it is necessary to make frequent adjustments to maintain a

constant perturbing current while measuring the voltage. Finally, the application of a perturbing current does, by its nature, affect the corrosion current which it is desired to estimate. Hence the technique is invasive.

There has been described in an article entitled "Corrosion measurements on reinforcing steel and monitoring of concrete structures" delivered at the Corrosion 87 Conference in San Francisco an improved technique for monitoring corrosion. The technique, described in more detail hereinafter, basically involves monitoring corrosion of a corroding element embedded in concrete by:

providing a passive current path for current flow from and to a corrosion half cell, said current path including said corroding element and current conducting means connected between said corroding element and the surface of the concrete and being electrically independent of said potential monitoring means;

monitoring the current flow along said current path, said current flow being solely current generated in the corrosion half cell; and

monitoring the potentials at the surface of the concrete prior to and during provision of said passive current path to detect the difference therebetween.

The passive current path is preferably provided by a zero resistance ammeter coupled to the concrete surface via a platinised titanium electrode. While having several advantages over the first-mentioned prior art, the technique has been found to be capable of improvement.

The present invention resides in improvements to an apparatus and method for monitoring corrosion of a corroding element embedded in concrete as defined above.

According to one aspect of the invention, there is

provided an apparatus for monitoring corrosion of a
corroding element embedded in concrete or like
substance, the corroding element forming with the
concrete or like substance a corrosion half cell, said
5 apparatus comprising:

means for monitoring the potential of said half
cell;

10 means for providing a current path for current
flow developed between an external probe having an
annular surface portion with a water-absorbing material
thereon for contacting the surface of the concrete and
the corroding element, said current path including said
corroding element, said probe and current conducting
means connected between said corroding element and said
15 probe; and

means for monitoring the current flow along said
current path, said current flow being solely current
generated in the corrosion half cell.

20 According to a second aspect of the invention,
there is provided a method of monitoring corrosion of a
corroding element embedded in concrete or like
substance and forming with the concrete or like
substance a corrosion half cell, which comprises the
steps of

- 25 a) connecting a current conducting means between
the corroding element and a probe having an
annular surface portion with a a water-absorbing
material thereon contacting the surface of the
concrete or like substance to provide a current
30 path along which corrosion current developed in
said half cell can flow; and
b) measuring said corrosion current.

The current monitoring device employed in the
apparatus of this invention preferably comprises a
35 support and a rotatable member mounted for rotation
relative to the support, the rotatable member carrying

about its circumferential surface a water absorbing member for contact with said surface and a conductive member adjacent the water absorbing member and in contact therewith, the conductive member being formed of a material which is substantially inert relative to the concrete or like substance and being recessed relative to the absorbent member so that it does not contact the surface in use.

The potential monitoring means is preferably constructed in accordance with the disclosure of GB 2157441, i.e. comprises a rotatable member mounted for rotation relative to a support, which rotatable member carries about its circumferential surface a water absorbing member for contact with the surface of said structure, which rotatable member is associated with an electrolytic half cell including an electrode and container means for receiving an electrolyte fluid to be in contact with the electrode and restricting means for providing an ionic path from the container means to the water absorbing member of said rotatable member, the restricting means permitting ions of said electrolytic fluid to transfer charge to ions in water absorbed by the water absorbing member, yet preventing any significant quantity of electrolyte fluid from reaching the said surface whereby, with the water absorbing member sufficiently wet to provide a conductive path from the surface of the restricting means, the electrolytic half cell forms with said corrosion half cell a full cell, the rotatable member also being associated with measuring means for measuring the potential of said full cell as an indication of the occurrence of said corrosion.

The potential monitoring is generally provided by potential monitoring means which comprises an electrolytic half cell capable of creating with said corrosion half cell a full cell the potential of which

can be measured as an indication of the occurrence of corrosion and which is electrically independent of said current monitoring.

5 Preferably, the apparatus of the invention is constructed as a combined monitoring device movable along the said surface, which device provides potential monitoring of said corrosion half cell in addition to current monitoring and in which the potential monitoring is electrically independent of said current
10 monitoring.

For reasons which will become apparent hereinafter, apparatus of this invention preferably comprises paired rotatable members mounted for rotation relative to a common support, the rotatable members
15 being rotatable members for current monitoring and potential measurement as described already herein. Indeed, in particularly preferred practice, provision is made for monitoring of potential of the half-cell at a location in advance of that at which current
20 monitoring and potential measurement occurs. A further rotatable member for potential measuring can then be mounted ahead of paired rotatable members as aforesaid.

Turning next to the use of apparatus embodying the invention, data obtained in such method may be utilised
25 in the plotting of graphs of monitored current versus the natural logarithm of time to extrapolate stable current data from instantaneous values of the monitored current. Preferably values of monitored current are recorded over a short time period, for example less
30 than ten seconds.

When apparatus embodying this invention comprises potential measuring means, then the latter will give a first indication of the potential of a corrosion half cell which is in existence. Monitoring of corrosion of
35 the corroding element then preferably takes place by a procedure comprising the steps of:

- a) obtaining a first indication of the potential of said corrosion half cell;
- b) measuring said corrosion current;
- c) while said corrosion current is flowing,
- 5 obtaining a second indication of the potential of said corrosion half cell; and
- d) utilising said first and second indications and said corrosion current to obtain data relating to the rate at which corrosion is occurring.

10 Further, to take into consideration drops in cell current which can affect the interpolation of monitored current values, instantaneous readings of measured current and the change in potential can be taken after a defined stabilising time.

15 For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:-

Figure 1 is a block diagram of an apparatus for
20 use with the present invention;

Figures 2A and 2B are maps of potential in a corroding structure;

Figure 3A and 3B are maps of corrosion current in the structure of Figures 2A and 2B;

25 Figure 4 is a graph showing the variation in potential and current along a portion of a corroding structure;

Figure 5 is a perspective view from one side of a current monitoring device;

30 Figure 6 is an enlarged side view of the wheel of the device of Figure 5;

Figure 7 is a perspective view from one side of a potential monitoring device;

35 Figure 8 is a perspective view from the other side of the monitoring device of Figure 7;

Figure 9 is a sketch showing a two device scan;

Figure 10 is a perspective view of a combined monitoring device; and

Figure 11 is an enlarged end view of the device of Figure 10.

5 Referring to Figure 1, which shows diagrammatically part of a reinforced concrete structure, there will now be described a "passive" or "non-invasive" corrosion monitoring technique.

10 A steel reinforcing bar 1 is embedded in concrete 2. As is well known in the art, and as is described in the above-referenced GB Patent 2157441, the environmental conditions of the structure can cause corrosion half cells to appear along the reinforcing bar 1. The corrosion monitoring apparatus to be
15 described includes potential monitoring components and corrosion current monitoring components. In one embodiment, the potential monitoring components, known per se, include a reference electrolytic half-cell 3, placed on the surface of the concrete 2 and of
20 conventional construction. By way of example a copper/copper sulphate cell or silver/silver chloride cell would be suitable. The corrosion half-cell forms with the reference half-cell 3 a full cell the potential of which can be measured by a voltmeter 4
25 connected between the electrode of the half-cell 3 and the reinforcing bar 1.

The corrosion current monitoring components comprise an inert electrode 5, a ZERO resistance
ammeter (ZRA) 6, that is an electronic ammeter such as
30 that described in "Operational Amplifiers", G.E. Clayton p163 section 8.11. Such an ammeter has a range of resistors to give a range of measurable currents, and can be considered to introduce an effective resistance of zero ohms into the current path. The
35 electrode 5 comprises platinum coated titanium wire and has one end 5a embedded in a porous sponge 50 which is

placed on the surface of the concrete 2. When simultaneous measurement of potential and current is required, the electrode 5 is physically but not electrically attached to the half-cell 3 so as to be placed closely adjacent thereto. As an example, the electrode 5 and the half cell 3 could be spaced apart by about 10 mm, and in any event preferably less than 25 mm.

As described in more detail below, the flow of corrosion current from the corrosion half-cell causes the local region around the electrode 5 to become slightly polarised, since the platinum acts as a local cathodic source which is superimposed onto any general or galvanic macro-corrosion cells occurring naturally on the steel. The effect of this polarisation can be monitored using the reference half-cell 3. The electrode 5 itself does not, or only negligibly, takes part in the reaction. The platinum electrode current measurements can also be used in conjunction with the external reference half-cell 3 to assess the polarisation on the steel reinforcement. As described below, the change in corrosion potential is measured and an estimate of the polarisation resistance value (termed R_p) is obtained.

In accordance with one embodiment of the invention, described hereinafter, the electrode 5 can be incorporated within a rotatable structure as shown in Figures 5 and 6.

A wheel 51 is rotatably mounted to a support or handle 141. The wheel 51 carries around its circumference an absorbent member in the form of a tyre 54 and, adjacent thereto, a conductive member comprising a platinum coated titanium annulus 53. The width in the radial direction of the annulus 53 is slightly less than that of the tyre 54 so that there is no direct contact between the surface of the structure

and the annulus when the wheel is rolled along the surface. Instead, electrical contact is made via the absorbent tyre which is kept moist with water or any other suitable conductive, non corrosive fluid. A suitably plated spring contact 60 is mounted to the handle and in contact with the annulus 53 to provide an electrical pick-off which provides the input, via a wire 52, to the current measuring components described earlier.

One form of potential monitoring device with a similar rotatable structure will now be described with reference to Figures 7 and 8.

The potential monitoring device uses a solid-state or 'DRY' half-cell e.g. a cell consisting of silver and silver chloride. Such a 'DRY' half-cell 35 consists of a silver rod coated with fused silver chloride salt. The silver/silver chloride electrode is based on the principle that the silver chloride, a porous glass, absorbs a surrounding potassium chloride solution which serves as an electrolyte.

A wheel 31, having a circumference of 600 mm, is free to rotate about a bearing coupled to a shaft. The rotating wheel 31 drives a shaft-encoder 33 which generates 150 pulses/rev. Around the rim of the wheel is a tyre 34 of water absorbent foam plastics material.

The sintered silver/silver chloride half-cell 35 (for example such as is described in British Patent Application No. 8429046) is on one side of the shaft, in a plastic holder 36 which screws into the body of a plastic cell chamber 37 so that only the silver chloride tip is in contact with the electrolyte (potassium chloride) contained in the chamber 37.

There is also located within the chamber a length of sintered water absorbent nylon rod which projects from the chamber 37 and bears against a plastic, perforated plate 62 in contact with the foam plastic

tyre 34. The nylon rod serves to provide an ionic path to enable an electrical connection to be made via the wheel 31 to the surface of the structure. Electrolyte passes from the rod to the wheel 31 via perforations in the plate 62.

On the other side of the shaft there is a reservoir chamber 40 in the form of a recess in the body of the shaft and having a clear plastic cover. Holes are drilled through the shaft such that the electrolyte (potassium chloride) within the reservoir chamber 40 can flow into the cell chamber 37. The reservoir chamber is so designed as to maintain the cell chamber 37 full of electrolyte whatever the attitude of the whole device. The reservoir chamber is able to be filled through an orifice (not shown) in the shaft of the device, which is then sealed when the chamber is full.

A handle 41 of the device is hollow and able to accommodate a small encapsulated, high input impedance, buffer amplifier. The input to this amplifier is terminated in a small smb socket, into which is plugged an smb plug on the end of an output cable 44.

The output cable 44 from the shaft encoder 33 passes through a gland in the handle 41 of the device, on the other side to that bearing the smb socket. Power and signal cables for the buffer amplifier and shaft-encoder are terminated within the handle by a 6-pin chassis mounting plug. External circuitry (to be described later) is connected to this plug.

The handle 41 of the device may be unscrewed from the shaft of the device, providing access to the buffer amplifier. A locking ring 46 is screwed on to lock the hollow handle onto the shaft of the device.

Referring to Figures 9 and 10, the above described current and potential monitoring devices can be combined to provide a combined monitoring device. This

device has a common handle or support carrying two types of rotatable wheel, one type having a structure as described with reference to Figures 5 and 6 and the other as described with reference to Figures 7 and 8.

5 The auxiliary components as described individually above are mounted on the common support to produce the combined device shown in Figures 10 and 11 in which like reference numerals denote the same parts as in Figures 5 to 8. As Figure 9 shows, an additional
10 potential measuring wheel device is mounted in front of the combined device to take a preliminary half-cell potential reading before current monitoring and potential measurement take place simultaneously.

Referring again to Figure 1, a method of
15 monitoring corrosion in concrete will now be described, using the stationary electrode 5 and half-cell 3.

The ZRA has terminals 11, 12 enabling it to be connected between the electrode 5 and the reinforcing bar 1 to create a passive current path 8, i.e. a path
20 containing no external potential or current source. For the avoidance of doubt, the term "passive current path" used herein has no connection with the current flowing on the surface of reinforcing steel in a non corrosive state, which current maintains a passive film
25 at the steel surface and is known in the corrosion art as "passive current".

In use, the platinum electrode 5 is maintained wet, by damping the sponge 50, both to ensure an adequate conductance path to the concrete and also to
30 establish a redox reaction on the platinum surface, which is dependent on the reduction of atmospheric oxygen.

With the ZRA 6 switched out of circuit, or disconnected using the switch 13, the reference half
35 cell 3 and voltmeter 4 are used in the known way to measure the potential (V_1) of the cell formed by the

reference half cell 3 and the corrosion half cell formed by the corroding steel bar 1 with the concrete 2. The ZRA 6 is then switched into circuit using the switch 13 to permit the corrosion current of the corrosion half cell to flow along the current path 8. After a stabilisation period of about one to two minutes, the current measured by the ZRA 6 is recorded. Then, with the current path 8 still connected, the potential reading (V_2) of the voltmeter 4 is taken.

The polarisation resistance R_p can then be calculated from the following:

$$\frac{V_2 - V_1}{I} = R_p \quad \text{Equ 1}$$

While an absolute value for polarisation resistance cannot normally be obtained for steel in concrete, "apparent" values obtained by Equ 2 have been found by the inventor to represent corrosion rates and can be used to enable comparative measures of corrosion rates to be made.

When a rotatable structure is used, the tyre 54 of the wheel 51 is sprayed with water.

When using the combined device, the potential is first measured by rolling the wheel along the surface of the concrete with the ZRA switched out of circuit. Then, the ZRA is switched into circuit and a second scan of the same region of the concrete surface is made. In this way traces of "rest" potential, polarised potential and polarising current (I_p) are plotted relative to positions on the concrete surface, from which the corrosion current I_{corr} can be estimated.

The technique using the ZRA is essentially non invasive. The current path 8 enables corrosion current generated in the corrosion half-cell to flow out of and back into the corrosion half-cell. In practice, it has been found that the current I_p measured by the ZRA is a

proportion of the actual corrosion current I_{corr} . There is no application of a perturbing (or invasive) current or voltage as with the prior art potentiostat technique.

5 It is an important advantage of the non invasive technique described herein that not only an average current flow but also current transients can be observed. Average current flow and the current transients are able to identify areas of corrosion and
10 provide an indication of the level of corrosion activity, including characteristic transients due to film breakdown and possible pitting type corrosion.

 The mechanism underlying the technique described herein is believed to be along the following lines. In
15 the corrosion half-cells formed along the steel, naturally occurring cathodes and anodes can be identified. The rate of reaction occurring at the cathode is altered by the coupling of the platinum electrode to the half cell. The cathodic rate at the
20 platinum electrode is greater than that of the naturally occurring cathodes and hence serves to upset the equilibrium of the naturally occurring half-cell. A new equilibrium is set up in the half-cell to take into account the greater cathodic reaction rate of the
25 electrode 5, and the changes in potential between the two equilibria can be monitored as discussed below. The technique has a considerable advantage over conventional techniques in that it is free-floating : i.e. the disruptive effect of perturbing current or
30 voltage is obviated.

 It has been found by the present inventors that the magnitudes of the measured I_p current and related potential change are dependent on the surface area of the electrode 5 in contact with the surface of the
35 concrete. To achieve a desired area of contact, point probes, line probes and circular probes are proposed.

However, it has been discovered that, where the combined rotatable device is not used, annular probes have a larger surface area in contact with the concrete and therefore provide a better galvanic effect.

It is possible to leave the measurement system coupled to the concrete for a period of time to obtain current and potential noise time records from which the 'noise' polarisation resistance may also be assessed. A comparison obtained on steel samples in NaCl & Ca(OH)₂ solution and in a concrete test block with macro corrosion cells is given in the Table set out below. The table also includes polarisation resistance data (R_{ap}) obtained using the conventional linear polarisation resistance method.

Comparison of Polarisation Data (kohm cm²)

Sample	R_{ap}	R_p
3% NaCl soln	5.8	7.2
sat. Ca(OH) ₂	1200	1700
concrete	1.9	1.7

Hence, in addition to providing a non-invasive and simple-to-apply technique for determining an indication of rate of corrosion, the free flowing current along current path 8 also provides valuable information about the noise and transients associated with the corrosion and hence the type of corrosion occurring.

Such effects are completely masked by the currently used techniques where a perturbing current is applied.

To avoid the need for two scans, a potential measuring wheel device can be used connected to the combined device, for example with a spacing of 100 mm, in such a way that the wheel of the potential measuring device gives a trace of 'rest' potential and is followed by the wheels of the combined device with the ZRA switched into circuit. Figure 10 is a sketch of the arrangement.

It will be apparent to a man skilled in the art that the corrosion rate values can only be obtained by considering the corrosion current per unit area of the structure. With the known linear polarisation technique, normally the area of steel being polarised is a test region of known area, typical $10-100\text{cm}^2$. However, whilst this is feasible for test specimens, or for test probes deliberately embedded into real structures at the time of construction, it may not be a practical system for the inspection of existing structures since the precise area of steel being polarised is unknown. Even in cases where probes are embedded into structures at the time of construction, they only relate to the actual corrosion occurring in the vicinity of the probe. Further, if, as in the case of the presently described embodiment of the invention, the actual steel matrix is to be polarised by an external auxiliary electrode then there will be a spread of potential from the position close to the auxiliary electrode but the polarisation will decay with distance.

To overcome these difficulties, guard ring techniques have been proposed for use in conjunction with the known linear polarisation techniques to determine the rate of corrosion on an actual structure, but without the need to use spaced apart embedded probes.

The concept of a guard ring is to restrict the area of the reinforcing matrix being polarised by a central counter electrode surrounded by a plurality of auxiliary electrodes in a ring thus simplifying data analysis. The guard ring provides counter polarisation to the surrounding steel matrix. The guard ring technique, suitable for use with the present invention is described in "Failure and Repair of Reinforced Concrete Structures", London. Pub. Oyez, Scientific

1981 by D.C. John. However, it is an advantage of the ZRA technique described above that, since it is non invasive and draws only a small current via the electrode 5, the influenced area is relatively small and easy to define. It is possible to derive an estimate of the influenced area by using the reference half-cell 3 to obtain potential values at grid points around the electrode 5. Once such an estimate has been made for a particular design of electrode 5, it can be assumed that that estimate will be valid for subsequent surveys using an electrode of that design.

Figures 3 and 4 are examples of data derived using the above described technique and show clearly the additional information derived over a conventional potential scan of the concrete (Figs. 2A and 2B).

A significant disadvantage of all previous systems for corrosion rate measurement is the time required for readings to stabilise. The decay curves for the polarising current, potential shifts and corrosion current plotted against time showed that the polarising current (I_p) decays in the first 30 seconds, substantially stabilising thereafter, which has given rise to the practice of taking readings after about 1 minute. The inventors have noted that a plot of the current against natural log of time shows a linear relationship. They have realised that it is therefore possible to predict the 'true' corrosion current from an instantaneous reading and the slope of a typical decay curve. The slopes and intercepts of the current vs log time graphs differ for active (corrosive) and passive (non-corrosive) areas.

The shift in potential due to polarisation on the other hand is virtually instantaneous and generally stable. Thus, using the above described apparatus, the corrosion current can be measured in one of two possible ways:

- a) use an instantaneous current value in conjunction with a potential change as described above to produce R_p values which have been found to successfully distinguish active and passive areas; and
- 5 b) use the intercept and initial slope (say at 5 seconds) of the current against log time graph to calculate the value of current at 1 minute.

CLAIMS:

1. An apparatus for monitoring corrosion of a corroding element embedded in concrete or like substance, the corroding element forming with the concrete or like substance a corrosion half cell, said apparatus comprising:

means for monitoring the potential of said half cell;

means for providing a current path for current flow developed between an external probe having an annular surface portion with a water-aborbing material thereon for contacting the surface of the concrete and the corroding element, said current path including said corroding element, said probe and current conducting means connected between said corroding element and said probe; and

means for monitoring the current flow along said current path, said current flow being solely current generated in the corrosion half cell.

2. An apparatus as claimed in claim 1, wherein the probe comprises a support and a rotatable member mounted for rotation relative to the support, the rotatable member carrying about its circumferential surface a water absorbing member for contact with said surface and a conductive member adjacent the water absorbing member and in contact therewith, the conductive member being formed of a material which is substantially inert relative to the concrete or like substance and being recessed relative to the absorbent member so that it does not contact the surface in use.

3. An apparatus as claimed in claim 1 or 2, comprising potential monitoring means which comprises an electrolytic half cell capable of creating with said corrosion half cell a full cell the potential of which can be measured as an indication of the occurrence of corrosion and which is electrically independent of said

current monitoring.

4. An apparatus as claimed in claim 3,
comprising a combined monitoring device movable along
the said surface, which device provides potential
5 monitoring of said corrosion half cell in addition to
current monitoring and in which the potential
monitoring is electrically independent of said current
monitoring.

5. An apparatus as claimed in claim 3 or 4
10 wherein the potential monitoring means comprises a
rotatable member mounted for rotation relative to a
support, which rotatable member carries about its
circumferential surface a water absorbing member for
contact with the surface of said structure, which
15 rotatable member is associated with an electrolytic
half cell including an electrode and container means
for receiving an electrolyte fluid to be in contact
with the electrode and restricting means for providing
an ionic path from the container means to the water
20 absorbing member of said rotatable member, the
restricting means permitting ions of said electrolytic
fluid to transfer charge to ions in water absorbed by
the water absorbing member, yet preventing any
significant quantity of electrolyte fluid from reaching
25 the said surface whereby, with the water absorbing
member sufficiently wet to provide a conductive path
from the surface of the restricting means, the
electrolytic half cell forms with said corrosion half
cell a full cell, the rotatable member also being
30 associated with measuring means for measuring the
potential of said full cell as an indication of the
occurrence of said corrosion.

6. An apparatus as claimed in claims 4 and 5,
which comprises paired rotatable members mounted for
35 rotation relative to a common support, which rotatable
members are rotatable members as defined in claims 2

and 5 respectively.

7. An apparatus as claimed in claim 6, which is constructed to provide monitoring of potential of said half cell at a location in advance of monitoring of current flow from said half cell at such location by means of a further rotatable member as defined in claim 5.

8. An apparatus as claimed in any preceding claim, wherein the current conducting means includes a platinum electrode.

9. An apparatus as claimed in any preceding claim, wherein the current monitoring means comprises a zero resistance ammeter.

10. An apparatus for monitoring corrosion of a corroding element embedded in concrete or like substance, substantially as hereinbefore described with reference to and as shown in Figure 1 in association with Figures 5 and 6 and optionally in additional association with Figures 7 and 8 of the accompanying drawings.

11. An apparatus for monitoring corrosion of a corroding element embedded in concrete or like substance, substantially as hereinbefore described with reference to and as shown in Figures 9 to 11 of the accompanying drawings.

12. A method of monitoring corrosion of a corroding element embedded in concrete or like substance and forming with the concrete or like substance a corrosion half cell, which comprises the steps of

a) connecting a current conducting means between the corroding element and a probe having an annular surface portion with a water-absorbing material thereon contacting the surface of the concrete or like substance to provide a current path along which corrosion current developed in

said half cell can flow; and

b) measuring said corrosion current.

13. A method as claimed in claim 11, wherein said probe has the structure defined in claim 2.

5 14. A method as claimed in claim 12 or 13, wherein a monitored current is plotted against the natural logarithm of time and there is carried out an extrapolation of stable current data from instantaneous values of the monitored current.

10 15. A method as claimed in claim 19, wherein values of monitored current are recorded over time periods of less than ten seconds.

16. A method as claimed in any one of claims 12 to 15, comprising the steps of:

15 a) obtaining a first indication of the potential of said corrosion half cell;

b) measuring said developed corrosion current;

c) while said corrosion current is flowing, obtaining a second indication of the potential of said corrosion half cell; and

20 d) utilising said first and second indications and said corrosion current to obtain data relating to the rate at which corrosion is occurring.

25 17. A method as claimed in claim 16, wherein instantaneous readings of measured current and change in potential are taken only after a defined stabilising time.

30 18. A method of monitoring corrosion of a corroding element embedded in concrete or like substance, substantially as hereinbefore described with reference to the accompanying drawings.